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Evaluation of bird repellent additives to a simulated pesticide carrier formation

J.R. Mason[†,‡*] and G. Epple[‡]
[†]USDA Animal and Plant Health Inspection Service, Denver Wildlife Research Center, c/o Monell Chemical Senses Center, 3500 Market Street, Philadelphia, PA 19104, USA and [‡]Monell, Chemical Senses Center, 3500 Market Street, Philadelphia, PA 19104, USA

No-till agriculture involves the use of pelleted and granular pesticides and chemically treated seeds. Some of these products kill birds. The present experiments were designed to investigate whether four candidate repellents (methyl anthranilate, *ortho*-aminoacetophenone, *d*-pulegone, and pine oil) would reduce consumption by European starlings (*Sturnus vulgaris*) of clay particles similar in size and shape to particles normally used for pesticide delivery. All substances reduced consumption ($P<0.05$), although none completely eliminated it. To achieve further reductions in consumption, other particle characteristics might be considered. These include the use of colors that make particles indistinct from the substrate, and a texture or particle size that diminishes the likelihood that particles will be ingested as grit.

Keywords: bird; chemosensory; pesticide; repellent; *Sturnus vulgaris*

Conservation farming is increasingly popular for both environmental and economic reasons (Crosson, 1982). These farming practices benefit wildlife by preserving food and cover, and by minimizing the use of broadcast spray applications of pesticides (Castrale, 1987). However, granular pesticides, pelleted baits, and chemically treated seeds are essential components of conservation farming, and some of these products are toxic to birds and rodents (Schafer *et al.*, 1983; Greig-Smith, 1988; US EPA, 1989; Best and Gionfriddo, 1991).

One method to reduce the ingestion of granular pesticides, pelleted baits, and chemically treated seeds by wildlife might be the use of repellent additives to these products. The available evidence suggests that such additives can substantially reduce consumption of pelleted baits by birds under some circumstances (Mason *et al.*, 1993). In two laboratory experiments and an outdoor aviary trial, cowbirds (*Molothrus ater*) were presented with pellets containing pesticide and methyl anthranilate, pellets containing pesticide but no methyl anthranilate, and carrier pellets without pesticide or methyl anthranilate. Consumption of any formulation was low, but the addition of methyl anthranilate significantly decreased bait loss in the laboratory and prevented the disappearance of bait in the outdoor aviary.

In the present experiments, methyl anthranilate, *ortho*-aminoacetophenone, *d*-pulegone, and pine oil were evaluated as candidate repellent additives to a simulated pesticide carrier formulation. In feeding trials, methyl anthranilate, *ortho*-aminoacetophenone and *d*-pulegone are generally repellent to vertebrates, albeit at different concentrations (Mason *et al.*, 1989, 1991; Mason, 1990; Nolte *et al.*, 1993). Pine oil is repellent to rodents in a variety of contexts (G. Epple, unpublished manuscript), but the effectiveness of this substance against birds is unknown. *A priori*, we expected that it might be less effective than the other substances because turpentine is not repellent to European starlings (*Sturnus vulgaris*) or common grackles (*Quiscula quisculus*; Mason and Bonwell, 1993).

*Corresponding author. Present address: Predator Ecology Project, USDA/APHIS/WS/NWRC, BNR-163, Utah State University, Logan, UT 8432-5295, USA.

Materials and methods

Subjects

Twenty European starlings were selected from the laboratory colony at the Monell Chemical Senses Center, and individually caged (cage dimensions: $61\times36\times41$ cm) at 23°C under a 12:12 h light:dark cycle. Before the experiment began, tap water and chow (Purina Flight Bird Conditioner) were provided *ad libitum*.

Chemicals

Reagent grade methyl anthranilate (CAS# 134-20-3) and *ortho*-aminoacetophenone (CAS# 551-93-9) were purchased from Aldrich Chemical Company (St. Louis, MO). Siberian pine oil was purchased from the Penn Herb Company (Philadelphia, PA).

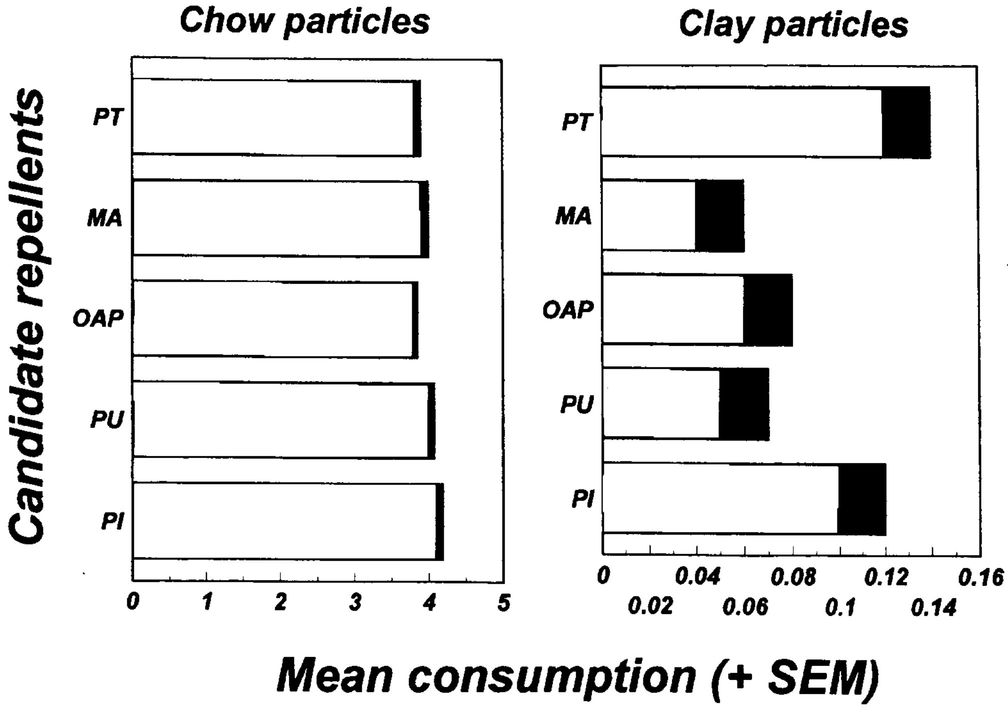

Figure 1. Mean consumption by European starlings of chow and clay granules during pre-treatment (PT), and during treatment trials in which granules were adulterated with methyl anthranilate (MA), *ortho*-aminoacetophenone (OAP), *d*-pulegone (PU) and pine oil (PI). Histograms represent the mean consumption capped by standard errors of the means

d-pulegone (CAS# 89-82-7) was donated by International Flavors and Fragrances (Union Beach, NJ). The purity of the pine oil was unknown; according to International Flavors and Fragrances, the purity of the *d*-pulegone was approximately 85% (L. Scharf, International Flavors and Fragrances, pers. commun.).

To simulate carrier particles, clay cat litter was passed through a #16 Standard Sieve, and the sieved particles were collected. The particles were bluish gray in color, and the particle size (> 1.18 mm diameter, ranging to 0.25 mm diameter) was essentially identical to the particle size used with 5% diazanon granules (EPA Registration Number 407-354-468, pers. obs.). To prepare test stimuli, samples of sieved particles were placed in a drying oven at 37°C for 72 h, and then mixed with each of the candidate repellents to produce repellent concentrations of 1.0% (volume/mass, v/m). Treated samples were stored in covered plastic containers at 1.7°C.

Procedure

Birds were randomly assigned to two groups ($n = 10$/group), and then adapted to an overnight (12 h) food deprivation schedule. This schedule remained in effect throughout the experiment. Every day for two consecutive weeks during the hour following light onset (08.00–09.00 h), each bird was presented with a tray containing 40 g of chow and 2 g of clay particles. The chow was light brown in color, and had been sieved so that all particles were < 1.18 mm in diameter. After 2 h, the trays were removed from the cages, chow and clay particles were separated by sieving, feces if any were removed, and then each of these samples was weighed to provide estimates of ingestion. All birds were permitted free access to chow and tap water from 10.00 to 11.00 until lights out (20.00).

The treatment period followed the second week of pretreatment. On each of 4 days, both groups of birds were presented with trays containing 40 g of chow and 2 g of clay particles adulterated with repellent (1.0% v/m). Group 1 was exposed to methyl anthranilate first, followed by *ortho*-aminoacetophenone, pulegone, and then pine oil. Group 2 birds were exposed to the stimuli in the opposite order. As in the pretreatment, the ingestion of chow and particles was estimated after 2 h, and then all animals were provided with free access to chow and tap water until lights out (20.00).

Analysis

The data (daily consumption of chow and clay particles) were evaluated in two single-factor repeated-measures ANOVAs. The factor in these ANOVAs was test (five levels). The mean ingestion during the last 4 days of the pre-treatment period was included as a level of the factor. Tukey post-hoc tests (Winer, 1962) were used to isolate significant differences among means.

Results

Evaluation of chow consumption failed to reveal any significant differences among pretreatment and treatment sessions ($F > 0.20$). However, evaluation of clay particle ingestion revealed significant differences among sessions ($F = 13.7$; df 4,52; $P < 0.001$). Post-hoc tests showed that ingestion during the pre-treatment period was significantly greater than ingestion in the presence of any of the repellents (*Figure 1*, $P<0.01$).

Discussion

All of the candidate repellents (methyl anthranilate, *ortho*-aminoacetophenone, *d*-pulegone, pine oil) significantly reduced particle ingestion by birds. However, in no case was consumption eliminated. For this reason, we conclude that whereas repellent additives may reduce pesticide hazards to wildlife, risks of incidental poisoning will persist, depending upon the toxicity of the pesticide in question. In addition, risks of poisoning are likely to be influenced by the species at risk (Best, 1995), the diets of these species (Norris *et al.*, 1975; Gionfriddo and Best, 1995) and environmental conditions (Best *et al.*, 1996).

To eliminate hazards of particulate and granular pesticides, a number of redundant features may be important. Besides the inclusion of a chemical repellent, these features might include the use of colors that make particles indistinct from the substrate (e.g. Greig-Smith and Rowney, 1987), and textures or particle sizes that diminish the likelihood that particles will be ingested as grit (Best and Gionfriddo, 1994).

Overall, relatively few studies have examined the factors that determine grit selection by birds. More research into the factors that influence grit/granule consumption by birds is needed, perhaps in the context of individual pesticides–carrier combinations. Only in this fashion will it be possible to determine whether pesticide granules can be modified to significantly reduce avian risks.

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